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14. ABSTRACT

A Wireless Vital Signs Monitor (WVSM) has been developed by the Office of Naval Research (ONR) and the United States Army Institute of Surgical Research (USAISR). This monitor incorporates several sensors from different manufacturers that can be implemented far out to the point of injury and adds complete trend analysis over four hours. Multicenter trials have been completed and the instrument is FDA approved. This WVSM is too bulky for field operations by US Special Forces (SOCOM), but functional prototypes of an alternative miniature wireless monitoring device with improved trend analysis even further out to the point of injury have now been delivered (SOCOM-Mini-medicTM). There have been no field tests to date. The primary objective of this project is to perform the first field tests of the SOCOM Mini-medic. The main focus is to validate the mini-Medic for combat casualty care (including, but not limited to, brain injury) in prehospital and hospitalized patients. Lessons learned from our previous and ongoing trials in trauma patients with and without brain injury will be applied.

15. SUBJECT TERMS
Combat casualty care, injury acuity score, blood pressure, heart rate

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TABLE OF CONTENTS

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OVERVIEW

The approved statement of work (SOW) and main questions related to the SOW for this project requires clinical data collection and analysis, and neither is complete. Therefore the primary focus of this annual report is to provide information on :

1) administrative and technical issues that have reduced enrollment

2) number of patients enrolled to date, number of disqualified patients if any and for what reasons, number of dropouts if any and why, will study meet its target number (state what that is or approved for) for clinical significance and if not what are the proposed strategies to address this shortfall, will study meet its target earlier than anticipated because of the uniformity of the data and if so, how that will impact the work

3) adverse events

4) progress to date

BODY OF ANNUAL REPORT

A. GOAL

To evaluate for the US Special Operations Command (SOCOM) a miniature, portable wireless vital signs monitor (MWVSM, Mini-medic™, www.athenagtx.com) and/or new algorithms based on non-invasively measured vital signs or other physiologic variables, that could aid in the triage and diagnosis of trauma patients with and without traumatic brain injury (TBI). The MWVSM consists of two components, both of which are the approximate size and weight of a cell phone: one is a sensor that is placed either on the forehead or the fingertip of a casualty and the other is a monitor that receives a wireless signal transmitted up to 100 m carried by the medic.

Initially, the MWVSM was the prototype of a new class of devices. In the 5 yrs since this project was initially conceived, and 3 yrs since it was approved and funded, there have been major advances in wireless monitoring technology. There are now several alternative miniature sensors and monitoring systems, both by Athena GTX and numerous other manufacturers, that might better serve the needs of SOCOM. There is no better place in the world to critically evaluate this technology because the Univ of Miami is one of three sites for training military trauma teams, and the only site for the US Army. We pride ourselves on incorporating the latest innovations in training, informatics, telemedicine, as well as continuously evaluating existing and novel diagnostic strategies. As part of continuous quality improvement, the protocols for prehospital transport, fluid resuscitation, as well as trauma ICU care are routinely evaluated and updated. The most important issues that will be answered in the final phase of this project relate to defining the limitations of the MWVSM with particular injury patterns and to determining suitable alternatives. Thus, we intend to provide all the performance data concerning the current MWVSM platform that was in the original application, plus provide additional information on the limitations of the technologies, plus provide suggestions for suitable alternatives. Altogether, this should provide SOCOM with enough information to make an informed decision on whether to recommend the current MWVSM, a new improved version, or an alternative, for far forward combat casualty care on 21rst century battlefields.

B. HYPOTHESIS

This project has been totally driven by the technological needs of SOCOM, rather than by a classical hypothesis. Basically, the MWVSM was developed by www.athenagtx.com to capture whatever useful biological information is possible from small sensors placed on the forehead (or at a peripheral extremity site) of up to 5 casualties, then wirelessly transmit to small cell-phone sized monitors carried by any first responder within range. The need was to triage, prioritize transport and to track changes in numerous casualties in an austere environment from a remote location. Within that context, to evaluate the MWVSM, we proposed the overall working hypothesis that: *changes in multiple parameters or derived variables monitored from the forehead (or extremity) of a severely injured patient correlate favorably with conventional vital signs monitors either before or after definitive treatment at a level 1 trauma center.*

C. EXPERIMENTAL QUESTIONS:

1) Does R wave and SpO2 detection from the MWVSM forehead (or peripheral) probe generate values that favorably compare to ECG and/or SpO2 monitored conventionally? If not, do the MWVSM values provide any useful information regarding casualty status? Is there another variable that would be more useful to measure from the forehead (e.g. near infrared spectroscopy (NIRS) or Bispectral EEG (BIS)) or extremity?

2) Does pulse wave transit time (PWTT) reflect blood pressure changes? If not, is there an alternative?

3) Can the “Murphy Factor” (a proprietary algorithm derived from MWVSM variables) be used as “trend monitor” (i.e. summarize trauma patient condition or change in condition, or predict the need for life-saving intervention as reliably as a conventional monitor? If not, can new or better algorithms

based on other vital signs or physiologic variables be developed?

4) Can heart rate variability (HRV)-related values (e.g., cardiac complexity and approximate entropy) summarize trauma patient condition or change in condition, or predict the need for life-saving intervention as reliably as standard monitors with ECG capability with or without HRV? If not, can new or better algorithms based on other non-invasively measured vital signs (e.g., NIRS or BIS) be developed?

D. ADMINISTRATIVE AND TECHNICAL ISSUES THAT HAVE REDUCED ENROLLMENT

1. late delivery of original MWVSM from manufacturer by project start date,
2. MWVSM software and hardware failures resulting in loss of data from enrolled patients
3. delivery delays of upgraded software and hardware from manufacturer
4. new EMS protocols which diverted eligible patients to a neighboring trauma center
5. turnover in prehospital EMS which resulted in a few protocol breaches
6. turnover in my staff and university hiring freeze that left us short staffed for a time

E. NUMBER OF PATIENTS ENROLLED TO DATE

Specific Task	Baseline plan date	revised plan date	completion date	status
Seek IRB Approval	12-May 11		16-May 11	complete
Seek exception to informed consent from DOD	12-May 11		16 May 11	complete
Hiring and training personnel; adjusting protocol	12 May 11			complete
Data collection from representative sample (400 est) patients during prehospital transport	27 Feb 13	27 May 15	18 Oct 2013	Complete: 151 patients recruited
Data collection from representative sample (400 est) patients in ER	27 Feb 14	27 May 15		106 patients recruited
Data collection from representative sample (20 est) patients with TBI in ICU	27 Feb 14	27 May 15		31 patients recruited
Share data with USAISR and ONR	27 Feb 14	27 May 15		
Develop algorithms or improved monitoring strategies to predict need for life saving interventions	27 Feb 14	27 May 15		

Pre-Hospital: Trauma = 161 (7 TBI), Non- Trauma = 20, [102 = finger, 43 = head, 13 = excl missing data]
Resus : Trauma = 106 (9 TBI), Non-trauma = 0, [101 = finger, 5 = head]
ICU : Trauma = 31 (8 TBI) , [Both head and finger = 31]

F. PROPOSED STRATEGIES TO ADDRESS SHORTFALL

We have overcome these obstacles by increasing efficiency and by developing protocols in alternative patient populations to accomplish the overall goal.

G. ADVERSE EVENTS

This is population is at high risk for injury-induced death or disability. The IRB approved protocol requires that all adverse events are reported to the human subjects committee for independent review. No adverse events have been attributed to this protocol.

H. SUMMARY OF PROGRESS

In the original application, progress toward the overall goal was to be marked by four milestones.

MILESTONE 1: completion of all certifications to conduct this observational trial with waiver of consent.
MILESTONE 2: completion of data collected from a representative sample of prehospital patients.
MILESTONE 3: completion of data collected from a representative sample of in-hospital patients.
MILESTONE 4 is marked by the derivation of algorithms based on vital signs that predict the need for life-saving interventions for pre-hospital and hospitalized trauma patients. Vital signs data will be correlated offline to clinical outcomes and the need for lifesaving interventions (based on patient records). Raw vital signs will be shared with scientists and physicians at ONR and USAISR to aid in the development of their own algorithms.

Milestone 1 is completed. Milestone 2 is more or less completed and some data have already been published. However, we continue to deploy MWVSM systems in the field and have asked EMS to continue sending us patients, so in that sense Milestone 2 is still open. We anticipate that maintaining this relationship with our prehospital partners might pay dividends in the future. We may get lucky with a rare patient that will give us unusual insight into the system performance. Alternatively, a new or improved MWVSM system may become available in the near future. However, virtually all our effort is dedicated to Milestones 3 &4.

Specifically, MWVSM sensors are now being placed on the forehead and extremity of trauma ICU patients with and without TBI. The phase and magnitude of these signals are compared to continuous signals from conventional bedside monitors, to address all four of the experimental questions described above.

At the time the original application was written, we had no experience working with AirRescue or other prehospital providers and no experience collecting field data from injured patients. The SOW was approved to collect data from 820 patients (400 in the prehospital area, 400 in the resuscitation area, and 20 in the ICU). It is now clear that we greatly overestimated the actual number of patients that will be required to address all the main questions and we will not meet those enrollment targets. Nevertheless, we will achieve the overall project goal, and answer all the questions.

The original enrollment targets were estimates based on power analysis and those power analyses were based on assumptions about several unknowns, especially on data variability, patient characteristics, and policies and protocols of prehospital providers. It turns out that some of the assumptions in the original proposal were wrong. For example, with a smaller sample size we have proof of concept that the MF outperforms standard vital signs as a triage tool (***J Trauma Acute Care Surgery*** 2014 Mar;76(3):743-9.), and is among the important findings from this project.

I. KEY RESEARCH ACCOMPLISHMENTS RELATIVE TO MAIN QUESTIONS

1. PREHOSPITAL This study population to date is comprised of 151 patients (108 trauma patients and 20 stroke and ST segment elevated myocardial infarction (STEMI) patients). An additional 23 prehospital patients were excluded because of missing or incomplete data (i.e., loss of peripheral signals for patients in extremis, lost or inaccessible prehospital run reports). The majority of prehospital transports have finger sensors for logistic reasons, i.e. many patients are strapped to a backboard and the head strap is in the exact location for the MWVSM forehead sensor. The data collection continues but interim data have been presented and published. The monitoring period varies from <10 min to >60 min. Some sensors fall off during transport. In many cases, valid data are obtained for only a portion of the prehospital time. We continue to enroll 1-2 patients per week and expect to add an additional 40-50 patients by the end of the funding period.

Table 1: Characteristics of prehospital patient population

median(interquartile range) or M±SD	trauma, n=108	non-trauma, n=20
monitoring time, min	21(20)	38±9
transport time, min	22±17	40±9
blunt/penetrating	83/15	na
age, yrs	45(21)	65±17
wt, lbs	178(50)	155(55)
gender,% male	81	65
SBP mm Hg	139±35	147(19)
HR ,beats/min	92±22	82±19
% receiving LSI	10.4	5.0
%mortality	10.8	0

Obviously the characteristics are completely different in the two patient groups. The main emphasis of this project is on trauma patients, but data are compared to the non-trauma patients to understand performance characteristics of the sensors and the specificity of the MF.

Table 2:
Paired Difference between vital signs measured with MWVSM and conventional monitor during prehospital transport

	trauma n=108		non-trauma n=20	
	heart rate	SpO2	heart rate	SpO2
paired difference	1.01±1.95	6.6±1.6	6.91±6.04	4.96±1.83
Paired t	t=0.52;	t=4.17;	t=1.14;	t=2.71;
	p=NS	p<0.001	p=NS	p<0.02

This shows over a 20-40 min prehospital monitoring period, the MWVSM heart rate sensor agrees with the heart rate measured by the conventional monitor (the difference in paired measurements is not significant), but the MWVSM SpO2 sensor does not (the difference in paired measurements is significant). It should be emphasized that continuous digital data from MWVSM are averaged over the entire transport time for each patient and compared to the average of intermittent spot checks from the standard monitor obtained from the prehospital run reports. This may not be the best way to look at these data, but they suggest that R wave detection in the MWVSM more or less agrees with a standard monitor: it deviates 1-6 beats/min relative to a standard monitor. However, the MWVSM SpO2 detector is consistently 5-7 % lower than the standard monitor.

Table 3: Comparison between MWVSM forehead and finger sensor within trauma patients

	forehead n=25	finger n=79

	heart rate	SpO2	heart rate	SpO2
paired difference	3.05±4.17	18.02±2.18	1.20±2.28	2.18±1.78
Paired t	t=0.73;	t=8.27;	t=0.53;	t=1.23;
probability	p=NS	p<0.001	p=NS	p=NS

These data show that the R wave detection and pulse oximeter in the MWVSM finger probe are more accurate and follow changes better than those in the forehead probe in trauma patients. The results of this trial led to a redesign of the method for affixing the forehead sensor to the skin.

The 108 patients suffered predominantly blunt trauma (83%), were mostly male (81%), age 45±21 yrs, with a median(interquartile range) injury severity score (ISS) 9(13). Those who received a LSI in either the field or the ER (n=51) had similar demographics, but higher ISS (19 vs 4) and mortality (24% vs 0%) (all $p<0.05$). LSI included intubation, tube thoracostomy, central line insertion, blood product transfusion, and operative intervention.

Table 4: Comparison between trauma patients who required LSI and those who did not

	None (n=57)	LSI (n=51)	p=
Age, yrs	43±20	48±21	0.946
Gender, % male	82	78	0.775
Mechanism, % blunt	81	86	0.775
ISS	4 (8)	19 (10)	<0.001
Mortality %	0	24	0.003

MF > 3 averaged over the entire transport time was superior to vital signs alone or in combination for identifying LSI. Prehospital data and MF from a MWVSM were compared to vital signs (SpO2, systolic blood pressure (SBP), and HR) from a conventional monitor. Sensitivity (Se), specificity (Sp), negative predictive value (NPV), positive predictive value (PPV), and area under the curve (AUC) were calculated.

Table 5: Diagnostic values of conventional vital signs and MWVSM for predicting need for LSI.

	Se	**Sp**	**NPV**	**PPV**	**AUC**	**p=**
SpO2 < 95	0.143	0.975	0.571	0.833	0.526	0.747
SBP <90	0.121	0.976	0.586	0.800	0.546	0.558
HR >100	0.314	0.786	0.740	0.550	0.549	0.536
HR,SBP,O2	0.486	0.762	0.640	0.630	0.616	0.142
MF > 3	0.414	0.875	0.622	0.750	0.665	0.038

In summary, prehospital data showed there are major demographic differences in the characteristics of trauma patients and non trauma patients. The MWVSM tracks heart rate within 1-6 beats/min, but the MWVSM SpO2 sensor consistently underestimates true SpO2 and this is almost entirely due to problems with the forehead sensor. The manufacturer was informed about this problem and designed a new method for attaching the forehead sensor to the skin. The preliminary indication is radically improved performance of the forehead sensor. MF calculated over an 18 min prehospital transport time has the potential to identify trauma patients who need a LSI, and is superior to conventional vital signs. Data from several hypotensive patients were excluded from the paired comparison and correlation analysis because of missing data for patients in extremis; specifically, the EMTs reported that the finger tip oximeter signal failed to register with the thready pulse characteristic of hemorrhagic shock. This observation suggests that using a forehead and finger sensor on the same patient and comparing the difference could be an accurate, specific, and precise indicator of shock state. For this reason, we have begun collecting data from ICU patients with both a forehead and peripheral sensor. We have also determined that the MF almost totally depends on the Glasgow Coma Score

(GCS), which is entirely subjective and may be difficult to obtain in chaotic field environments. For this reason, we have begun collecting data from ICU patients with a bispectral index sensor; it may be provide an alternative to GCS.

2. **TRAUMA RESUSCITATION AREA** This study population is comprised of 103 trauma patients. The data collection (7/12 to 8/13) is complete, but have not been fully analyzed.

Table 6: Characteristics of patients in trauma resuscitation area

median(interquartile range) or M±SD	N=103
monitoring time, min	65(87)
blunt/penetrating	85/13
age, yrs	44±19
wt, lbs	180(43)
gender,% male	76
SBP mm Hg	140±37)
HR ,beats/min	90±24
% receiving LSI	38
ISS	10(13)
%mortality	7.4

Table 7: Comparison between MWVSM and conventional monitor in the resuscitation area

	Finger sensor, n=98		Forehead sensor, n=5	
	heart rate	SpO2	heart rate	SpO2
paired difference	1.2±1.2	0.3±1.0	12.9±11.4	-5.2±19.3
t	1.05	0.3	2.125	-0.27
probability	NS	NS	NS	NS

These data show an almost perfect agreement between the MWVSM finger or forehead sensors and the conventional vital signs monitor. This could reflect the fact that these patients are more hemodynamically stable, the sampling interval is longer, or that the monitoring session was controlled by our team rather than the prehospital providers (the same people selected the patients, affixed the sensors, and collected the data).

3. **TRAUMA ICU** This study is ongoing and so far consists of 23 patients with and without TBI. A forehead and a peripheral sensor or placed on every patient and the monitoring period is 60 min.

Table 8: Characteristics of patients in trauma ICU

median(interquartile range) or M±SD	N=23
monitoring time, min	60±0
blunt/penetrating	44/30
age, yrs	45±21
gender,% male	78
Weight, kg	80(20)
% TBI	35
% Finger + forehead sensors	100

EXPECTED OUTCOMES FROM ICU (DATA COLLECTION ONGOING)

At the time of this progress report, the sample size is not large enough for any meaningful comparison. This data set will be important to resolve several issues raised the other data sets. A major problem is that there is a continuous digital record from the MWVSM, but only intermittent spot checks manually entered into the nursing notes, patient chart, or paramedic run report from the standard vital signs monitor. Thus, we are basically comparing a continuous signal to an intermittent signal. Synchronized digital data from the MWVSM and the standard hemodynamic monitor in the ICU will allow a direct comparison of the phase and magnitude relationships between the heart rate and SPO2 signals and allow a more reliable test of whether PWTT tracks mean arterial pressure changes. Also help to determine whether the finger sensor actually outperforms the forehead sensor.

J. SUMMARY & CONCLUSIONS

1. There have been no safety issues or adverse events.
2. The study objectives will be achieved with fewer than 800 patients enrolled.
3. We are on track to have unique data from a significant number of trauma patients from the point of injury through the entire hospital course.
4. An injury acuity algorithm has the potential to identify prehospital trauma patients who need a LSI, and is superior to conventional vital signs.
5. The MWVSM finger and forehead sensors have different performance characteristics.

K. PUBLICATIONS/PRESENTATIONS DIRECTLY RELATED TO APPROVED SOW

Juried or refereed journal articles:

1) Van Haren RM, Thorson CM, Valle EJ, Busko AM, Jouria JM, Livingstone AS, Namias N, Schulman CI, Proctor KG: Novel prehospital monitor with injury acuity alarm to identify trauma patients who require life saving intervention. ***J Trauma Acute Care Surgery*** 2014 Mar;76(3):743-9

2) Van Haren RM, Ryan ML, Thorson CM, Namias N, Livingstone AS, Proctor KG: Bilateral near infrared spectroscopy for detecting traumatic vascular injury. ***J Surg Res.*** 2013 Sep;184(1):526-32

3) Thorson CM, Ryan ML, Pereira R, Olloqui J, Otero CA, Schulman CI, Livingstone AS, Proctor KG: Change in hematocrit during trauma assessment predicts bleeding even with ongoing fluid resuscitation ***Amer Surgeon*** 2013 Apr;79(4):398-406.

4) Thorson CM, Van Haren RM, Ryan ML, Pereira R, Olloqui J, Guarch GA, Barrera JM, Busko AM, Livingstone AS, Proctor KG: Admission hematocrit and transfusion requirements after trauma. ***J Am Coll Surg*** 2013 Jan;216(1):65-73. Epub 2012 Nov 21.

5) Ryan ML, Thorson CM, Otero CA, Vu T, Schulman CI, Livingstone AS, Proctor KG. Initial Hematocrit in Trauma: A Paradigm Shift? ***J Trauma Acute Care Surg.*** 2012 Jan;72(1):54-9; discussion 59-60.

6) Ogilvie MP, Pereira BMT, Ryan ML, Gomez-Rodriguez JC, Pierre EJ, Livingstone AS, Proctor KG: Bispectral Index (BIS) to monitor propofol sedation in trauma patients: ***J Trauma***. 2011 Nov 71(5):1415-21.

7) Ryan ML, Ogilvie MP, Pereira BMT, Gomez-Rodriguez JC, Manning RJ, Vargas P, Duncan RC Proctor KG: Heart rate variability is an independent predictor of morbidity and mortality in hemodynamically stable trauma patients. ***J Trauma***. 2011 Jun 70(6):1371-79 discussion 1379-80.

Other works, presentations and abstracts

1) Valle EJ, Allen CJ, Jouria JM, Namias N, Livingstone AS, Schulman CI, Proctor KG: Do pre-hospital life saving interventions delay transfer or improve survival at a level 1 urban trauma center?
   a) Submitted 1/24/2014 to Florida Chapter, American College of Surgeons for the Seventh Annual Edward M. Copeland Resident Paper Competition Weston, FL May, 2014
   b) Submitted 2/28/2014 to the Surgical Forum, American College of Surgeons 2014 Clinical Congress, San Francisco, CA Oct , 2014

2) Allen CJ, Tashiro J, Valle EJ, Thorson C, Schulman C, Neville H, Proctor KG, Sola JE. Initial hematocrit guides the use of blood transfusion in the pediatric trauma patient. Accepted for presentation, 14th Annual John M. Templeton Jr. Pediatric Trauma Symposium, Philadelphia, PA March, 2014

3) Van Haren RM, Thorson CM, Valle EJ, Busko AM, Guarch GA, Jouria JA, Blackbourne LH, Livingstone AS, Namias N, Proctor KG: Novel prehospital monitor with injury acuity algorithm to identify patients who require life saving intervention. Presented at 72nd Annual Meeting of the American Association for the Surgery of Trauma and Clinical Congress of Acute Care Surgery, San Francisco, CA Sep 2013

4) Van Haren RM, Thorson CM, Valle EJ, Guarch GA, Busko AM, Namias N, Livingstone AS, Proctor KG: Prehospital triage tool to predict life saving interventions. Presented at 2012 Annual Meeting, American College of Surgeons, Florida Committee on Trauma Resident Paper Competiton, Gainesville, FL Oct 2012.

5) Van Haren RM, Ryan ML, Thorson CM, Curia E, Busko AM, Namias N, Livingstone AS, Proctor KG: Bilateral near infrared spectroscopy: a potential tool for detecting vascular injuries.
   a) Presented at South Florida Society for Vascular Surgery 2012 Annual Scientific Sessions, Islamorada, Florida Keys. Oct 2012
   b) Presented at Academic Surgical Congress New Orleans, LA Feb 2013

6) Van Haren RM, Thorson CM, Ryan ML, Curia E, Barrera JM, Busko AM, Guarch GA, Namias N, Proctor KG: Non-invasive monitoring technologies from the frontline to the FST and beyond:
   a) Presented at Florida Medical Association Poster Symposium Boca Raton, FL Jul 2012
   b) Presented at Military Health System Research Symposium MHSRS/ATACCC 2012, Fort Lauderdale, FL, Aug 2012
   c) Presented at University of Miami Annual Postdoctoral Fellows Research Day. Miami, FL, Sep 2012.

7) Thorson CM, Van Haren RM, Ryan ML, Guarch GA, Curia E, Busko AM, Namias N, Livingstone AS, Proctor KG: Hematocrit during initial trauma triage: Presented at Military Health System Research Symposium MHSRS/ATACCC 2012, Fort Lauderdale, FL, Aug 2012

8) Thorson CM, Van Haren RM, Ryan ML, Pereira R, Olloqui J, Guarch GA, Curia E, Barrera J, Busko AM, Livingstone AS, Proctor KG. Admission Hematocrit Predicts Transfusion Requirements in Trauma Patients
   a) Presented at 2011 American College of Surgeons Florida Committee on Trauma Resident Paper Competition, Miami, FL, Nov 2011
   b) Presented at 5th Annual Copeland Resident Paper Competition Florida Chapter American College of Surgeons, Sarasota, FL May 2012 (***1rst place research Award**)

9) Ryan ML, Thorson CM, Otero CA, Vu T, Schulman CI, McKenney MG, Livingstone AS, Proctor KG. Initial Hematocrit in Trauma: A Paradigm Shift? Presented at 70th AAST Annual Meeting Chicago, IL, Sept 2011 (***Resident Travel Scholarship)** http://www.aast.org

10) Ryan ML, Thorson CM, Gomez-Rodriguez JC, Otero CA, Vu T, Pereira BMT, Garcia GD, Livingstone AS, Proctor KG. Bilateral near infrared spectroscopy (NIRS): a potential tool for monitoring limb perfusion after battlefield extremity vascular injuries. Presented at ATACCC2011, Advanced Technology Applications to Combat Casualty Care, Ft Lauderdale, FL Aug, 2011.

11) Thorson CM, Ryan ML, Otero CA, Vu T, Manning RJ, Schulman CI, Livingstone AS, Proctor KG. Early drop in hematocrit during initial trauma resuscitation is not just dilutional.
   a) Presented at 4th Annual Copeland Resident Paper Competition 58th annual meeting Florida Chapter, American College of Surgeons, Orlando, FL, March 2011.
   b) Presented at 6th Annual Florida Medical Association Poster Symposium Orlando, FL, July 2011.
   c) Presented at ATACCC2011, Advanced Technology Applications to Combat Casualty Care, Ft Lauderdale, FL Aug, 2011